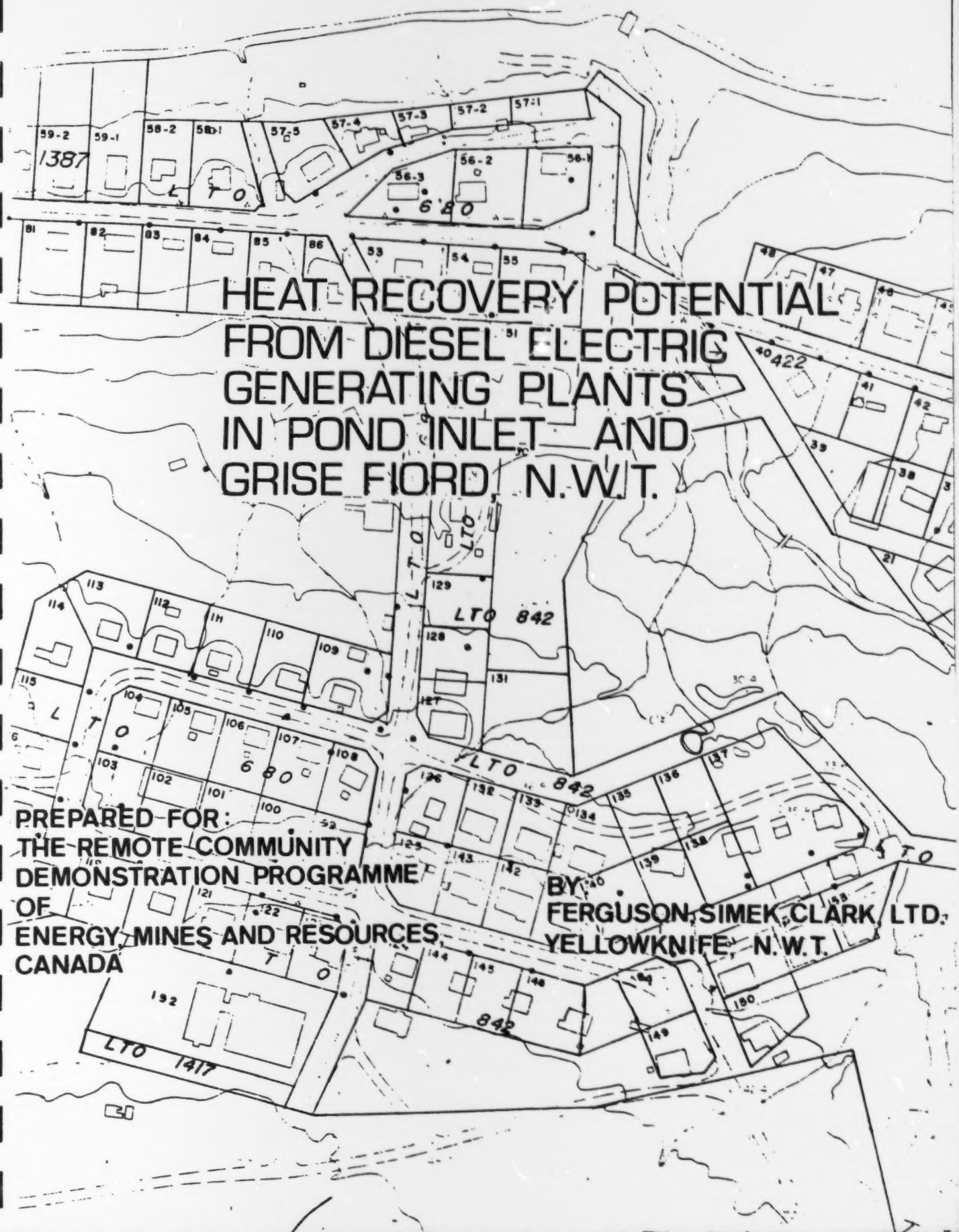

HEAT RECOVERY POTENTIAL FROM DIESEL ELECTRIC GENERATING PLANTS IN POND INLET AND GRISE FIORD, N.W.T.

PREPARED FOR:
THE REMOTE COMMUNITY
DEMONSTRATION PROGRAMME
OF
ENERGY, MINES AND RESOURCES
CANADA

BY:
FERGUSON SIMEK CLARK LTD.
YELLOWKNIFE, N.W.T.

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EXECUTIVE SUMMARY

This preliminary technical-economic report concerns the energy recovery potential (for space heating) in two small communities of the Canadian High Arctic: Pond Inlet (population:705), and Grise Fiord (population:105).

The objective of the study was to quickly test the cost-effectiveness/feasibility of recovering heat from diesel electric generators currently on-site in both communities. More detailed studies could provide refined conclusions and recommendations.

The methodology consisted of doing multiple runs of computer programs written by the contractor. The programs calculate energy values of heat production,recovery and market. They also give the economic break-even point of diesel electric sets for a full and partial market in each community, (given a complex array of technical and financial/systems/market assumptions in Appendices A and B respectively).

The layout of Grise Fiord is linear whereas Pond Inlet is comparitively compact in shape. Pond Inlet has 1000 KW generator capacity, while Grise Fiord has 400 KW.

The report concludes that there is some potential for heat recovery at both community sites, but the partial Pond Inlet Market presents the best opportunity for a more complete study with an investment break-even period of 6 years.

The reasons for the more advantageous break-even period relate to the greater volume of heat energy market and denser configuration of the partial Pond Inlet market, which in turn lessen the initial capital cost and minimize operational line energy losses.

The study was conducted in August 1983 for the Remote Community Demonstration Program of Energy, Mines and Resources Canada.

HEAT RECOVERY POTENTIAL
GRISE FIORD AND POND INLET
FOR COMMUNITY WASTE HEAT
FROM
DIESEL ELECTRIC GENERATING PLANTS

PREPARED FOR:

ENERGY, MINES AND RESOURCES CANADA
YELLOWKNIFE CREO OFFICE

BY:

FERGUSON SIMEK CLARK LIMITED
AUGUST, 1983

PRELIMINARY ANALYSIS OF HEAT RECOVERY POTENTIAL AT GRISE FIORD AND POND INLET, N.W.T. FOR COMMUNITY WIDE HEATING OPERATIONS USING DIESEL ELECTRIC WASTE HEAT

General

The analysis for Grise Fiord and Pond Inlet was carried out in accordance with standard engineering practices and techniques used for waste heat recovery projects undertaken in the Arctic.

As requested, the review was carried out using the entire community heated building inventory and compared to the heat production of the diesel generation plant. These results are presented technically and financially as the "Pond Inlet CREO" and "Grise Fiord CREO".

A second analysis was carried out on a limited section of each community which was selected after the results of the full community data were known. These results are included technically and financially as "Pond Inlet Partial Market CREO" and "Grise Fiord Partial Market CREO".

DISCUSSION

The methodology used is included in the back of this report as Appendix 'A'.

Pond Inlet

A review of the technical results of the Pond Inlet Source and Market Analysis reveals that the monthly heat market at peak demand exceeds the monthly heat available by a factor of 2.5 for the entire community. In addition, because of the length of the mains required due to the layout of the town, the average system heat loss for Exhaust plus Jacket Water equals two thirds of the heat available at peak conditions. The losses actually exceed the heat produced during months six and seven. If one considers Exhaust Only, the distribution and branch losses in the system always exceed the Exhaust Heat that can be recovered. For Jacket Water consideration, there is a surplus of waste heat Only in months 1, 2, 3, 11 and 12 after line losses.

The market utilization factors tell the story in that only 3% of the market heat would be satisfied by using Jacket Water; none of the market would be satisfied using Exhaust; and a combination of Exhaust and Jacket water would satisfy 28% of the market. From previous experience, these numbers are significantly lower than the financial requirements for a payout within the life of the system. For this reason, a financial payback was not undertaken for the "Pond Inlet CREO" community source and market analysis.

Recognizing that the extended distribution lines would produce excessive loss for the waste heat that was being produced, a "Pond Inlet Partial Market CREO" was undertaken. This market is outlined in the Pond Inlet Map and is essentially the area east at the generating station which includes the school, a number of houses and two garages.

A review of this analysis shows that the average monthly distribution system losses are much lower than the full community case and that the market utilization factors for the Exhaust plus Jacket Water case is approximately 70%. This number is significantly high to warrant a financial review of the investment and costs, and is included as the waste heat recovery cost avoidence benefits for Pond Inlet Partial Market CREO Recovery Option. The analysis is self-explanatory, and the Exhaust plus Jacket Water appears to be the most attractive alternative with a break-even occurring between years 6 and 7. A look at the Jacket Water Only installation shows a break even at year 11 while the Exhaust Only option has a break even after the system life.

Grise Fiord

A similar approach to that of Pond Inlet was adopted for Grise Fiord, and the community analysis is entitled, "Grise Fiord CREO". A review of the Waste Heat Recovery Source and Market Analysis reveals a situation similar to Pond Inlet (and is in fact more pronounced in that the generator output and subsequent heat production is lower for the community). The average monthly heat loss for the distribution system is of the order of 60,000 Kilowatt hours while the best maximum monthly heat available is only 74,000 kilowatt hours. Such an arrangement shows the total community recovery option as unrealistic and is best understood by reviewing the potential market utilization summary. For Jacket Water Only and Exhaust Only Heat, the distribution losses exceed the heat available from these individual sources. The combined Exhaust plus Jacket and Water has a small surplus of heat in months 1, 2, 3, 1., and 12 and is a net loser of heat for the remaining months. Again, in a manner similar to Pond Inlet, the market utilization factors are very low and do not warrant further study.

A "Grise Fiord Partial Market CREO" was also reviewed and includes the School, the Garage and Water Treatment Plant. All of these buildings are located within close proximity of the diesel plant and are capable of using the entire heat at peak market. (See Grise Fiord Map). Note that maximum monthly heat available is 74,000 kilowatts while the maximum monthly market is 76,000 kilowatts, a very good match. Additionally, the length of the service mains are Only 340 metres and require Only three service connections. The potential market utilization summary shows the harmony that exists with such an arrangement in that the Jacket Water Only has a market utilization of 38%, the Exhaust Only has a market utilization of 22%, while the Exhaust Plus Jacket Water Option has a market utilization slightly in excess of 75%.

The financial analysis and study of cost avoidants benefits are given as the "Grise Fiord Partial Market CREO" Recovery Options.

Note that the payouts exceed the time period for the Pond Inlet partial system. This is due in part to the higher costs associated with Grise Fiord as well as the fact that the absolute fuel savings are smaller while the fuel prices in Pond Inlet and Grise Fiord are of similar values.

RECOMMENDATIONS

Based on this preliminary analysis, it is our opinion that Pond Inlet offers the more attractive alternative for a Phase 2 indepth study for community heat recovery. The strategy in the Phase 2 portion would be to arrange the distribution system in such a manner as to account for the total rejected heat available from the power plant, including allowances for future expansion as the system load grows both in terms of production and use.

TECHNICAL & FINANCIAL ANALYSIS

POND INLET

TECHNICAL & FINANCIAL ANALYSIS

WASTE HEAT RECOVERY - SOURCE AND MARKET ANALYSIS

POND INLET CPEU

GENERATOR CAPACITY = 1000 kW SUPERCHARGED

MO	GENERATOR OUTPUT (KWH)	HEAT PRODUCED (KWH) JACKET	EXHAUST	COMBINED
1	2e5669.0	233137.6	275651.3	515248.9
2	243319.0	206958.0	236165.0	443023.0
3	24de28.0	210080.7	242029.8	452110.6
4	212090.0	180e52.3	208126.0	388778.3
5	186209.0	161160.4	185669.7	346830.1
6	151690.0	130950.5	150865.5	281816.0
7	148110.0	127762.4	147623.0	275385.4
8	154467.0	136593.9	157367.2	293961.1
9	192540.0	164719.7	189760.0	354479.7
10	222329.0	189936.8	217691.8	406628.6
11	251400.0	217294.1	244579.9	456874.0
12	270540.0	227504.3	262103.2	489607.6

MAX. MONTHLY HEAT PRODUCED (KWH) = 515289.

MO	HEAT USED IN-PLANT (KWH) JACKET	EXHAUST	RECOVERABLE HEAT (KWH) JACKET	EXHAUST	COMBINED
1	11565.0	0.0	215900.7	151718.2	367618.9
2	11333.0	0.0	184232.1	130440.7	314672.9
3	9557.0	0.0	190019.7	133116.4	323136.1
4	7989.0	0.0	163630.7	114469.3	278100.0
5	7366.0	0.0	145736.4	102118.3	247854.7
6	5717.0	0.0	118986.0	82976.0	201662.0
7	5424.0	0.0	116140.3	81082.6	197222.9
8	5815.0	0.0	123949.2	86551.9	210501.2
9	7462.0	0.0	149013.2	104368.0	253381.2
10	9084.0	0.0	170415.4	119725.0	290140.4
11	9321.0	0.0	192358.4	134518.9	326877.4
12	10496.0	0.0	205633.1	144156.8	349789.9

MAX. MONTHLY HEAT AVAILABLE (KWH)= 367619.

MARKET ANALYSIS

SPECIFIED (OTHER USERS) - WATER SUPPLY SYSTEM

MO	DEGREE-DAYS	MONTHLY HEAT MARKET NON-INDUST	INDUST	OTHERS	COMBINED
1	1494.0	819907.2	5481.6	10455.0	834743.8
2	1448.0	794662.4	5207.2	10130.0	857499.6
3	1527.0	838017.6	5582.8	8226.0	901826.4
4	1176.0	645388.8	4280E.4	5845.0	694040.2
5	836.0	458796.8	3043J.4	3574.0	492801.2
6	511.0	280436.8	18690.4	2835.0	301872.2
7	405.0	222264.0	14742.0	2941.0	239947.0
8	420.0	230496.0	15288.0	4076.0	249860.0
9	562.0	319401.6	21184.8	6113.0	346699.4
10	873.0	479102.4	31777.2	8348.0	519227.6
11	1193.0	654718.4	43425.2	9360.0	708003.6
12	1409.0	773259.2	51287.6	9985.0	834531.8

MAX. TOTAL MARKET (KWH) = 901826.

WATER DISTRIBUTION SYSTEM OPTION	PIPE SIZE (MM)	FLOW RATE (L/S)	AVERAGE MONTHLY HEAT LOSS MAINS (KWH)	BRANCH (KWH)	SYSTEM (KWH)
JW ONLY	76.	6.45	61480.	110979.	172419.
EX ONLY	51.	2.27	57719.	128155.	185874.
EX + JW	76.	5.49	73752.	128155.	201907.

LENGTH OF MAINS (METRES) = 1600.
NO. OF SERVICE CONNECTIONS = 149.

MO	POTENTIAL MARKET UTILIZATION SUMMARY (KWH) PRODUCED	RECOVERABLE	JW ONLY	EX ONLY	EX + JW
1	515288.9	367618.9	43481.4	0.0	165711.8
2	443023.0	314672.9	11812.8	0.0	112765.8
3	452110.6	323136.1	17600.4	0.0	121229.0
4	388778.3	278100.0	0.0	0.0	76192.9
5	346830.1	247854.7	0.0	0.0	45947.6
6	281816.0	201662.0	0.0	0.0	0.0
7	275385.4	197222.9	0.0	0.0	0.0
8	293961.1	210501.2	0.0	0.0	8594.1
9	354479.7	253791.2	0.0	0.0	51474.0
10	406628.6	290140.4	0.0	0.0	88233.3
11	456874.0	326877.4	19933.1	0.0	124970.2
12	489607.6	349789.9	33213.8	0.0	147882.8
		ANNUAL	TOTAL		
	4704774.3	3360957.6	126047.5	0.0	943001.5

SYSTEM UTILIZATION FACTORS JW ONLY	EX ONLY	EX + JW	MARKET UTILIZATION FACTORS JW ONLY	EX ONLY	EX + JW
0.0483	0.0215	0.2219	0.0375	0.0000	0.2808

WASTE HEAT RECOVERY - SOURCE AND MARKET ANALYSIS

PUMP INLET PARTIAL MARKET CREW

GENERATOR CAPACITY = 1000 KW SUPERCHARGED

MO	GENERATOR OUTPUT (KWH)	HEAT PRODUCED (KWH) JACKET	EXHAUST	COMBINED
1	285669.0	239437.6	275851.3	515288.9
2	243349.0	205458.0	237165.0	443023.0
3	248628.0	210080.7	242029.8	452110.6
4	212090.0	180852.3	208126.0	328778.3
5	188209.0	161160.4	185669.7	346830.1
6	151670.0	130350.5	150865.5	281816.0
7	148110.0	127962.4	147423.0	275385.4
8	158457.0	136593.9	157367.2	293961.1
9	192580.0	164710.7	189760.0	354470.7
10	222329.0	188946.8	217681.8	406628.6
11	251400.0	212294.1	244579.9	456874.0
12	270540.0	227504.3	262103.2	489607.6

MAX. MONTHLY HEAT PRODUCED (KWH) = 515289.

MO	HEAT USED IN-PLANT (KWH) JACKET	EXHAUST	RECOVERABLE HEAT (KWH) JACKET	EXHAUST	COMBINED
1	11565.0	0.0	215900.7	151718.2	367618.9
2	11333.0	0.0	183232.1	130440.7	314672.9
3	9557.0	0.0	190019.7	133116.4	323136.1
4	7989.0	0.0	163630.7	114469.3	278100.0
5	7356.0	0.0	145736.4	102118.3	247854.7
6	5717.0	0.0	116586.0	82976.0	201662.0
7	5424.0	0.0	116140.3	81082.6	197222.9
8	5815.0	0.0	123949.2	86551.9	210501.2
9	7462.0	0.0	145013.2	104368.0	253381.2
10	9084.0	0.0	170415.4	119725.0	290140.4
11	9321.0	0.0	192358.4	134518.9	326877.4
12	10496.0	0.0	205633.1	144156.8	349789.9

MAX. MONTHLY HEAT AVAILABLE (KWH)= 367619.

MARKET ANALYSIS

SPECIFIED (OTHER USERS) - WATER SUPPLY SYSTEM

MO	DEGREE-DAYS	MONTHLY HEAT MARKET NON-INDUST	INDUST	OTHERS	COMBINED
1	1494.0	430272.0	54381.6	10455.0	495108.6
2	1448.0	417024.0	52707.2	10130.0	479861.2
3	1527.0	439776.0	55582.8	8226.0	503584.8
4	1176.0	338688.0	42806.4	5854.0	387348.4
5	836.0	240768.0	30430.4	3574.0	274772.4
6	511.0	147168.0	19600.4	2835.0	169603.4
7	405.0	116640.0	14742.0	2941.0	134323.0
8	420.0	120960.0	15288.0	4076.0	140324.0
9	582.0	167616.0	21184.8	6113.0	194913.8
10	873.0	251424.0	31777.2	8348.0	291549.2
11	1193.0	343544.0	43425.2	9860.0	396869.2
12	1409.0	405792.0	51287.6	9985.0	467064.6

MAX. TOTAL MARKET (KWH) = 503585.

WATER DISTRIBUTION SYSTEM OPTION	PIPE SIZE (MM)	FLOW RATE (L/S)	AVERAGE MONTHLY HEAT LOSS MAINS (KWH)	BRANCH (KWH)	SYSTEM (KWH)
JW ONLY	76.	6.45	34560.	37986.	72546.
EX ONLY	51.	2.27	32467.	43865.	76332.
EX + JW	76.	5.49	41485.	43865.	85351.

LENGTH OF MAINS (METRES) = 900.
NO. OF SERVICE CONNECTIONS = 51.

MO	POTENTIAL MARKET UTILIZATION SUMMARY (KWH) PRODUCED	RECOVERABLE	JW ONLY	EX ONLY	EX + JW
1	515288.9	367618.9	143354.5	75386.2	282268.3
2	443023.0	314672.9	111685.9	54108.7	229322.2
3	452110.6	323136.1	117473.5	56784.4	237785.5
4	328778.3	278100.0	91084.5	38137.2	192749.4
5	346830.1	247854.7	73190.1	25786.3	162594.1
6	281816.0	201662.0	46139.8	6644.0	116311.4
7	275385.4	197222.9	43594.1	4750.8	111872.3
8	293961.1	210501.2	51403.0	10219.9	125150.6
9	354470.7	253381.2	76467.0	28035.9	169030.5
10	406628.6	290140.4	97869.2	43393.0	204789.8
11	456874.0	326877.4	119812.2	58186.9	241526.7
12	489607.6	349789.9	133486.9	67824.7	264439.3
	4704774.3	ANNUAL 3360957.6	TOTAL 1105160.7	469257.8	2336750.1

SYSTEM UTILIZATION FACTORS JW ONLY	EX ONLY	EX + JW	MARKET UTILIZATION FACTORS JW ONLY	EX ONLY	EX + JW
0.2564	0.1212	0.5142	0.3288	0.1396	0.6953

WASTE HEAT RECOVERY - COST AVOIDABLE BENEFITS

POND INLET PARTIAL MARKET CREO RECOVERY OPTION - JU ONLY

PRESENT VALUE - CAPITAL INVESTMENT = $ 685000.00

FINANCIAL EVALUATION

PAYMENT NO.	TOTAL FUEL SAVING PV	PRINCIPAL OUTSTANDING PV
1	$ 56021.48	$ 628976.52-
2	$ 114198.29	$ 550031.72-
3	$ 172039.18	$ 492960.82-
4	$ 230481.00	$ 435559.00-
5	$ 289178.62	$ 375621.38-
6	$ 348956.95	$ 316143.05-
7	$ 409813.95	$ 256119.05-
8	$ 467455.63	$ 195544.37-
9	$ 530586.05	$ 134413.95-
10	$ 592277.29	$ 72722.71-
11	$ 654534.51	$ 10465.49-
12	$ 717362.89	$ 52362.89
13	$ 780767.69	$ 115767.69
14	$ 844754.17	$ 179754.17
15	$ 909327.69	$ 244327.69
16	$ 974493.63	$ 309493.63
17	$ 1040257.42	$ 375257.42
18	$ 1106623.55	$ 441624.55
19	$ 1173600.55	$ 508600.55
20	$ 1241191.00	$ 576191.00

TOTAL FUEL SAVING = 121446. LITRES PER YEAR
DISCOUNT RATE = 9 %; FUEL INFLATION RATE = 10 %

BREAK - EVEN AT YEAR 11

POND INLET PARTIAL MARKET CREO RECOVERY OPTION - EX ONLY

PRESENT VALUE - CAPITAL INVESTMENT = $ 595000.00

FINANCIAL EVALUATION

PAYMENT NO.	TOTAL FUEL SAVING PV	PRINCIPAL OUTSTANDING PV
1	$ 24127.59	$ 570872.41-
2	$ 48476.54	$ 546523.46-
3	$ 73048.87	$ 521951.13-
4	$ 97846.63	$ 497153.37-
5	$ 122871.90	$ 472128.10-
6	$ 148126.76	$ 446873.24-
7	$ 173613.31	$ 421386.69-
8	$ 199333.68	$ 395666.32-
9	$ 225290.02	$ 369709.98-
10	$ 251494.50	$ 343515.50-
11	$ 277919.24	$ 317080.72-
12	$ 304596.59	$ 290403.41-
13	$ 331519.65	$ 263481.35-
14	$ 358687.70	$ 236312.30-
15	$ 386106.00	$ 208894.00-
16	$ 413775.85	$ 181224.15-
17	$ 441699.55	$ 153300.45-
18	$ 469879.43	$ 125120.57-
19	$ 498317.84	$ 96682.16-
20	$ 527017.16	$ 67982.84-

TOTAL FUEL SAVING = 51557. LITRES PER YEAR
DISCOUNT RATE = 9 %; FUEL INFLATION RATE = 10 %

BREAK - EVEN AFTER SYSTEM LIFE

POND INLET PARTIAL MARKET CREO RECOVERY OPTION - EX + JU

PRESENT VALUE - CAPITAL INVESTMENT = $ 815000.00

FINANCIAL EVALUATION

PAYMENT NO.	TOTAL FUEL SAVING PV	PRINCIPAL OUTSTANDING PV
1	$ 120147.44	$ 694852.56-
2	$ 241397.16	$ 573602.83-
3	$ 363759.26	$ 451240.74-
4	$ 487243.94	$ 327756.06-
5	$ 611861.51	$ 203138.49-
6	$ 737622.37	$ 77377.63-
7	$ 864536.99	$ 49536.99
8	$ 992615.96	$ 177615.96
9	$ 1121869.98	$ 306869.99
10	$ 1252309.91	$ 437309.91
11	$ 1383946.33	$ 568946.33
12	$ 1516790.51	$ 701790.51
13	$ 1650853.48	$ 835853.48
14	$ 1786146.37	$ 971146.37
15	$ 1922680.48	$ 1107680.48
16	$ 2060467.20	$ 1245467.20
17	$ 2199516.01	$ 1384516.01
18	$ 2339844.52	$ 1524844.52
19	$ 2481459.43	$ 1666459.43
20	$ 2624371.54	$ 1809371.54

TOTAL FUEL SAVING = 256765. LITRES PER YEAR
DISCOUNT RATE = 9 %; FUEL INFLATION RATE = 10 %

BREAK - EVEN AT YEAR 6

GRISE FIORD

TECHNICAL & FINANCIAL ANALYSIS

WASTE HEAT RECOVERY - SOURCE AND MARKET ANALYSIS

GPISE FIORU CREO

GENERATOR CAPACITY = 400 KW SUPERCHARGED

MO	GENERATOR OUTPUT (KWH)	HEAT PRODUCED (KWH) JACKET	EXHAUST	COMBINED
1	56770.0	49115.5	56585.0	105700.5
2	49920.0	43355.5	49949.0	93304.5
3	49100.0	42663.0	49151.2	91814.2
4	40130.0	35435.9	40275.7	75421.5
5	41510.0	36222.8	41731.5	77954.3
6	30900.0	27040.6	31152.9	58193.5
7	29000.0	25366.4	29352.4	54848.7
8	31950.0	28031.9	32295.0	60326.9
9	38540.0	33697.6	38810.9	72498.4
10	39790.0	34755.6	40041.3	74796.9
11	53240.0	46152.7	53171.7	99324.4
12	48420.0	42068.3	48487.1	90577.3

MAX. MONTHLY HEAT PRODUCED (KWH) = 105700.

MO	HEAT USED IN-PLANT (KWH) JACKET	EXHAUST	RECOVERABLE HEAT (KWH) JACKET	EXHAUST	COMBINED
1	3600.0	0.0	43059.7	31121.7	74181.5
2	3420.0	0.0	37767.7	27472.0	65239.7
3	3210.0	0.0	37319.9	27033.2	64353.0
4	3010.0	0.0	30293.6	22205.6	52490.2
5	2330.0	0.0	32951.6	22952.3	55034.0
6	1740.0	0.0	23948.6	17134.1	41082.7
7	700.0	0.0	23512.1	16149.3	39661.4
8	800.0	0.0	25830.3	17762.2	43592.5
9	900.0	0.0	31103.2	21346.0	52449.2
10	1050.0	0.0	31937.8	22022.7	53960.6
11	2750.0	0.0	41035.1	29244.4	70339.5
12	3800.0	0.0	36183.9	26669.0	62852.8

MAX. MONTHLY HEAT AVAILABLE (KWH)= 74181.

MARKET ANALYSIS

SPECIFIED (OTHER USERS) - N/A

MO	DEGREE-DAYS	MONTHLY HEAT MARKET NON-INDUST	INDUST	OTHERS	COMBINED
1	1553.0	186360.0	48453.6	0.0	234813.6
2	1648.0	173760.0	45177.6	0.0	218937.6
3	1531.0	183720.0	47767.2	0.0	231487.2
4	1234.0	149080.0	38500.8	0.0	186580.8
5	805.0	107400.0	27924.0	0.0	135324.0
6	557.0	66840.0	17378.4	0.0	84218.4
7	429.0	51480.0	13384.8	0.0	64854.8
8	485.0	58200.0	15132.0	0.0	73332.0
9	692.0	83040.0	21590.4	0.0	104630.4
10	1027.0	123240.0	32042.4	0.0	155282.4
11	1273.0	152760.0	39717.6	0.0	192477.6
12	1465.0	175800.0	45708.0	0.0	221508.0

MAX. TOTAL MARKET (KWH) = 234814.

WATER DISTRIBUTION SYSTEM OPTION	PIPE SIZE (MM)	FLOW RATE (L/S)	AVERAGE MONTHLY HEAT LOSS MAINS (KWH)	BRANCH (KWH)	SYSTEM (KWH)
JW ONLY	38.	1.29	27145.	29048.	56193.
EX ONLY	25.	0.46	24718.	33544.	58262.
EX + JW	32.	1.11	28058.	33544.	61602.

LENGTH OF MAINS (METRES) = 1000.
NO. OF SERVICE CONNECTIONS = 39.

POTENTIAL MARKET UTILIZATION SUMMARY (KWH) MO	PRODUCED	RECOVERABLE	JW ONLY	EX ONLY	EX + JW
1	105700.5	74181.5	0.0	0.0	12579.7
2	93304.5	65239.7	0.0	0.0	3837.9
3	91814.2	64353.0	0.0	0.0	2751.3
4	75421.5	52490.2	0.0	0.0	0.0
5	77954.3	55034.0	0.0	0.0	0.0
6	58193.5	41082.7	0.0	0.0	0.0
7	54848.7	39661.4	0.0	0.0	0.0
8	60326.9	43592.5	0.0	0.0	0.0
9	72498.4	52449.2	0.0	0.0	0.0
10	74796.9	53,60.6	0.0	0.0	0.0
11	99324.4	70339.5	0.0	0.0	8737.3
12	90577.3	62852.8	0.0	0.0	1251.1
		ANNUAL TOTAL			
	954761.3	675237.0	0.0	0.0	28957.8

SYSTEM UTILIZATION FACTORS JW ONLY	EX ONLY	EX + JW	MARKET UTILIZATION FACTORS JW ONLY	EX ONLY	EX + JW
0.0298	0.0286	0.0590	0.0000	0.0000	0.0429

WASTE HEAT RECOVERY - SOURCE AND MARKET ANALYSIS

GRISE FIORD PARTIAL MARKET CASE

GENERATOR CAPACITY = 800 KW SUPERCHARGED

MO	GENERATOR OUTPUT (KWH)	HEAT PRODUCED (KWH) JACKET	EXHAUST	COMBINED
1	56700.0	49115.5	56595.0	105700.5
2	49420.0	43355.5	49949.0	93304.5
3	49100.0	42663.0	49151.2	91814.2
4	40530.0	35045.9	40375.7	75421.5
5	41510.0	36222.8	41731.5	77954.3
6	30900.0	27040.8	31152.9	58193.5
7	29000.0	25446.4	29342.4	54468.7
8	31950.0	28031.9	32295.0	60326.9
9	39540.0	33687.6	38810.8	72498.4
10	39730.0	34755.6	40041.3	74796.9
11	53240.0	46152.7	53171.7	99324.4
12	48420.0	42088.3	48489.1	90577.3

MAX. MONTHLY HEAT PRODUCED (KWH) = 105700.

MO	HEAT USED IN-PLANT (KWH) JACKET	EXHAUST	RECOVERABLE HEAT (KWH) JACKET	EXHAUST	COMBINED
1	3600.0	0.0	43059.7	31121.7	74181.5
2	3420.0	0.0	37767.7	27472.0	65239.7
3	3210.0	0.0	37319.9	27033.2	64353.0
4	3010.0	0.0	30293.6	22206.6	52490.2
5	2330.0	0.0	32091.8	22952.3	55034.0
6	1740.0	0.0	23948.6	17134.1	41082.7
7	700.0	0.0	23512.1	16149.3	39661.4
8	800.0	0.0	25830.3	17762.2	43592.5
9	900.0	0.0	31103.2	21346.0	52449.2
10	1080.0	0.0	31937.8	22022.7	53960.6
11	2750.0	0.0	41095.1	29244.4	70339.5
12	3800.0	0.0	36183.9	26669.0	62852.8

MAX. MONTHLY HEAT AVAILABLE (KWH)= 74181.

MARKET ANALYSIS

SPECIFIED (OTHER USERS) - N/A

MO	DEGREE-DAYS	MONTHLY HEAT MARKET NON-INDUST	INDUST	OTHERS	COMBINED
1	1553.0	27954.0	48453.6	0.0	76407.6
2	1448.0	26054.0	45177.6	0.0	71231.6
3	1531.0	27556.0	47769.2	0.0	75325.2
4	1234.0	22212.0	38500.8	0.0	60712.8
5	895.0	16110.0	27924.0	0.0	44034.0
6	557.0	10026.0	17378.4	0.0	27404.4
7	429.0	7722.0	13384.8	0.0	21106.8
8	485.0	8730.0	15132.0	0.0	23862.0
9	692.0	12456.0	21590.4	0.0	34046.4
10	1027.0	18486.0	32042.4	0.0	50529.4
11	1273.0	22914.0	39717.6	0.0	62631.6
12	1465.0	26370.0	45708.0	0.0	72078.0

MAX. TOTAL MARKET (KWH) = 76408.

WATER DISTRIBUTION SYSTEM OPTION	PIPE SIZE (MM)	FLOW RATE (L/S)	AVERAGE MONTHLY HEAT LOSS MAINS (KWH)	BRANCH (KWH)	SYSTEM (KWH)
JW ONLY	38.	1.29	9229.	2234.	11464.
EX ONLY	25.	0.46	8404.	2580.	10984.
EX + JW	32.	1.11	9540.	2580.	12120.

LENGTH OF MAINS (METRES) = 340.
NO. OF SERVICE CONNECTIONS = 3.

MO	POTENTIAL MARKET UTILIZATION SUMMARY (KWH) PRODUCED	RECOVERABLE	JW ONLY	EX ONLY	EX + JW
1	105700.5	74181.5	31596.0	20137.5	62061.5
2	93304.5	65239.7	26304.0	16487.7	53119.8
3	91814.2	64353.0	25856.1	16048.9	52233.1
4	75421.5	52490.2	18819.9	11222.3	40370.3
5	77954.3	55034.0	20617.9	11968.1	42914.0
6	58193.5	41082.7	12486.8	6149.8	27404.4
7	54468.7	39661.4	12048.3	9165.0	21106.8
8	60326.9	43592.5	14366.6	6778.0	23862.0
9	72498.4	52449.2	19639.5	10361.7	34046.4
10	74796.9	53960.6	20474.1	11038.4	41840.8
11	99324.4	70339.5	29631.4	18260.1	58219.6
12	90577.3	62852.8	24720.1	15684.7	50732.9
	954781.3	ANNUAL 675237.0	TOTAL 256558.8	149302.3	807911.4

SYSTEM UTILIZATION FACTORS JW ONLY	EX ONLY	EX + JW	MARKET UTILIZATION FACTORS JW ONLY	EX ONLY	EX + JW
0.2934	0.1850	0.5606	0.3800	0.2211	0.7522

GOVERNMENT OF CANADA
ENERGY , MINES AND RESOURCES

WASTE HEAT RECOVERY - COST AVOIDANCE BENEFITS

GRISE FIORD PARTIAL MARKET CREO RECOVERY OPTION - JW ONLY

PRESENT VALUE - CAPITAL INVESTMENT = $ 196000.00

FINANCIAL EVALUATION

PAYMENT NO.	TOTAL FUEL SAVING PV	PRINCIPAL OUTSTANDING PV
1	$ 13704.67	$ 184291.33-
2	$ 27543.10	$ 170456.90-
3	$ 41503.45	$ 156495.54-
4	$ 55593.90	$ 142406.10-
5	$ 69812.60	$ 128187.40-
6	$ 84161.75	$ 113838.25-
7	$ 98642.55	$ 99357.45-
8	$ 113256.19	$ 84743.81-
9	$ 128003.91	$ 69996.09-
10	$ 142886.92	$ 55113.08-
11	$ 157906.48	$ 40093.52-
12	$ 173063.83	$ 24936.17-
13	$ 188360.24	$ 9639.76-
14	$ 203796.98	$ 5796.98
15	$ 219375.34	$ 21375.34
16	$ 235096.63	$ 37096.63
17	$ 250962.15	$ 52962.15
18	$ 266973.22	$ 68973.22
19	$ 283131.18	$ 85131.18
20	$ 299437.38	$ 101437.38

TOTAL FUEL SAVING = 28193. LITRES PER YEAR
DISCOUNT RATE - 9 %; FUEL INFLATION RATE - 10 %

BREAK - EVEN AT YEAR 13

GRISE FIORD PARTIAL MARKET CREO RECOVERY OPTION - EX ONLY

PRESENT VALUE - CAPITAL INVESTMENT = $ 211000.00

FINANCIAL EVALUATION

PAYMENT NO.	TOTAL FUEL SAVING PV	PRINCIPAL OUTSTANDING PV
1	$ 7977.62	$ 203022.38-
2	$ 16028.44	$ 194971.56-
3	$ 24153.11	$ 186846.89-
4	$ 32352.33	$ 178647.67-
5	$ 40626.76	$ 170373.24-
6	$ 48977.11	$ 162022.89-
7	$ 57404.06	$ 153595.94-
8	$ 65908.33	$ 145091.67-
9	$ 74490.62	$ 136509.38-
10	$ 83151.65	$ 127848.35-
11	$ 91892.13	$ 119107.87-
12	$ 100712.80	$ 110287.20-
13	$ 109614.40	$ 101385.60-
14	$ 118597.66	$ 92402.34-
15	$ 127663.33	$ 83336.67-
16	$ 136812.18	$ 74187.82-
17	$ 146044.97	$ 64955.03-
18	$ 155362.45	$ 55637.55-
19	$ 164765.42	$ 46234.58-
20	$ 174254.65	$ 36745.35-

TOTAL FUEL SAVING = 16407. LITRES PER YEAR
DISCOUNT RATE - 9 %; FUEL INFLATION RATE - 10 %

BREAK - EVEN AFTER SYSTEM LIFE

GRISE FIORD PARTIAL MARKET CREO RECOVERY OPTION - EX + JW

PRESENT VALUE - CAPITAL INVESTMENT = $ 310000.00

FINANCIAL EVALUATION

PAYMENT NO.	TOTAL FUEL SAVING PV	PRINCIPAL OUTSTANDING PV
1	$ 27139.11	$ 282860.89-
2	$ 54527.20	$ 255472.80-
3	$ 82166.56	$ 227833.44-
4	$ 110059.49	$ 199940.51-
5	$ 138208.32	$ 171791.68-
6	$ 166615.40	$ 143384.60-
7	$ 195283.09	$ 114716.91-
8	$ 224213.79	$ 85786.21-
9	$ 253409.91	$ 56590.09-
10	$ 282873.88	$ 27126.12-
11	$ 312608.16	$ 2608.16
12	$ 342615.23	$ 32615.23
13	$ 372897.60	$ 62897.60
14	$ 403457.79	$ 93457.79
15	$ 434298.35	$ 124298.35
16	$ 465421.85	$ 155421.85
17	$ 496830.98	$ 186830.98
18	$ 528528.07	$ 218528.07
19	$ 560516.06	$ 250516.06
20	$ 592797.52	$ 282797.52

TOTAL FUEL SAVING = 55814. LITRES PER YEAR
DISCOUNT RATE - 9 %; FUEL INFLATION RATE - 10 %

APPENDIX A

GENERAL DISCUSSION AND DIESEL GENERATING HEAT RECOVERY SYSTEMS

A. TECHNICAL DISCUSSION - DIESEL GENERATING HEAT RECOVERY SYSTEMS

DIESEL ENGINES

Diesel engines are available in sizes up to about 16,000 brake horsepower and can be fueled by a wide range of petroleum products of which #2 fuel oil is most popular. The engines are also fired with natural gas in combination with pilot liquid fuel.

Operating speeds of diesel engines usually vary from less than 600 RPM to 1,800 PRM, depending on size, generator characteristics and design time between overhauls, which normally vary from a minimum of 20,000 to 30,000 hours.

GENERATORS

Generators are matched to the prime movers by considering the efficient operation of both. Generator efficiency is a non-linear function of load as described by Graph 1.

HEAT RECOVERY

The amount of heat rejected will vary depending on engine design. Graphs 2, 3 and 4 describe typical heat balances for common engine configurations.

Exhaust temperatures for the four stroke engines are approximately 650°C at full load and 550° at 60% load. Two cycle engines operate at lower exhaust gas temperatures, especially at light loads due to the scavenger air volumes. The lower temperature gas ranges from 375°C at full load to 250°C at low loads. This high volume low temperature gas offers less efficient exhaust gas heat recovery possibilities.

JACKET HEAT CONSIDERATIONS

As stated previously, water cooling circuits in the block and exhaust manifolds must remove about 30% of the heat input to the engine. With engine operation at temperatures of above 80°C condensation from combustion products should not be a problem. Engines operating at 120°C and 200 kPa have modified gaskets and seal design so that they operate satisfactorily at these temperatures. Maximum engine temperature variation through the engine should be limited to 10°C to avoid thermal stress and flow rates should be kept within manufacturer's design limits. Circulation pumps may be engine mounted and driven or electric and remote. For elevated temperature operation, the pumps should have modified seals to work satisfactorily.

Engine castings may crack if exposed to sudden cooling such as a large process or intermittent heating load that temporarily overloads the system. Storage tanks provide an excellent buffer for such cases where water systems are involved.

For steam systems, a back pressure regulator is used to keep engine temperatures uniform. In the ebullient system, where fluid density variations induce flow through the engine, very little temperature difference exists between inlet and outlet. It is extremely important that precautions are taken to ensure back-pressure is maintained at all times as a sudden loss in pressure will result in steam bubble expansion in the engine which would interfere with circulation and result in overheating of critical engine areas.

The ebullient system requires that engine coolant passages be arranged for gravity circulation and free ejection of bubbles of steam. The typical arrangement is to slope engine coolant passages upward to encourage gravity flow and permit free release of steam to the separator.

The free convection cooling system is less dependent on mechanical accessories and is more readily arranged for completely independent assembly of each engine with its own coolant system.

EXHAUST GAS RECOVERY

The practical limitations of exhaust heat transfer equipment is based on a recommended maximum exhaust temperature of 120^{o}C. Depending on the initial temperature, 50 to 60% of the available exhaust heat can be recovered.

Recovery boilers should be designed for easy removal of soot on the exhaust side and an ability to clean the water side. The boilers can also be used as surge tanks, steam separators and fluid regulators.

The recovery equipment must not have an adverse effect on the engine's ability to do work. A prime consideration is the backpressure imposed on the engine exhaust. Limiting backpressures vary widely with the make of engine, but in general the range is 150 mm water gauge.

Heat recovery silencers are designed to ba adapable to most engines, with efficiency determined by the initial exhaust temperature and heat transfer surface.

There is very little data available on the effect of water vapour in the exhaust gas. However, a simple equation can be applied to determine quantitively the feasibility of heat recovery application for any given engine:

$$Q = W \times .003 (T_1 - 150)$$

where Q = heat recovery, kW
W = exhaust flow, kg per hour
T_1 = exhaust temperature, ^{o}C

specific heat of gas = .0003 $kW/_{kg - C}$

If engine data is not available, an approximatation of .29 kW of heat per horsepower can be used.

The design of heat recovery boilers should be in accordance with the ASME Code for the working pressure required. Since the temperature levels in most exhaust systems are not excessive, it is common practice to use flange or firebox quality steel for pressure parts, and low carbon steel for the non-pressure components. Wrought iron or copper may be used to improve heat transfer capacities.

LUBRICATING SYSTEM

The operating temperature of the engine affects the proportion of heat removed by the lube oil. In addition, the temperature of the lubricant must remain between 70^{o} and $90^{o}C$ with longer life expected at lower temperatures.

Engine manufacturers usually size their oil cooler heat transfer surfaces on the basis of $55^{o}C$ entering coolant water and without provision for additional heat gains to the lubricant that occur with high engine operating temperatures. For applications where jacket water temperatures exceed $105^{o}C$, the economical temperature for recovered heat from the oil cooler is about 70^{o} minimum.

Raw water should be avoided for use in oil coolers unless it is free of silt, calcium carbonates, sand or other contaminants. A domestic water heater may be installed on this circuit to provide a reserve heat exchanger.

In northern applications, utilidor domestic water recirculation heating lines offer an opportunity to use oil cooler heat due to the low grade required.

TURBOCHARGERS

Turbocharging on diesel engines permit more air to be forced into the cylinders so that larger quantities of separately injected fuel can be burned. Since the gas and air mixture will ignite at some specific temperature, pressure relationship, the lower the inlet air temperature, the higher the compression ratio can go before spontaneous combustion (pre-ignition) occurs.

For this reason aftercoolers are used to reduce the turbo charger outlet air temperature before entering the cylinders. Generally, water at $30^{o}C$ is used for this application and is a premium coolant because of the volumes and low temperature required.

GENERAL INSTALLATION PROBLEMS*

Cleanliness of the circulating fluid systems is necessary because the internal coolant passages of the engine are not readily accessible for service. The installation of piping, heat exchangers, valves and accessories must include provisions for internal cleaning of these ciruits before they are placed in service. Coolant fluids must be non-corrosive and free from salts, minerals or chemical additives that will deposit on hot engine surfaces or that will form sludge in relatively inactive fluid passages. In general, engines cannot be effectively drained and washed internally without major disassembly, so any chemical treatment of the coolant fluid that produces sediment or sludge is undesirable.

As an inital step toward maintaining clean coolant surfaces, it is necessary to severely limit fresh water makeup. The coolant system should be tight and free from leaks. Softened water of mineral free water is effective for initial fill and makeup. Forced circulation hot water systems may require nothing more than minor corrosion inhibiting additives to assure long, trouble-free service, and this feature is one of the major assets of hot water heat recovery systems.

The ebullient cooling method offers some special hazards for water treatment. Evaporation takes place in the engine and the concentration of dissolved minerals will increase at this critical location.

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This problem can be minimized by encouraging high flow rates, with gravity or forced cirulation, and by reducing to a negligible value the addition of minerals into the system. In any case, the water treatment must be adequate to prevent corrosion from free oxygen brought in with returned condensate and makeup water. Additional treatment should control corrosion in the heat recovery muffler and steam separator and in the condensate system. If the cost of pumping the water and the discount in utilization temperature can be absorbed in the system design, a hot water system is indicated as first preference. Most of the engines now available were designed for forced circulation of the coolant.

Where several engines are used in one process, independent coolant systems for each machine must be provided to avoid a complete plant shutdown from a common coolant system component failure. Each unit is a separate package with its own controls, heat exchangers and makeup system. Such independence also leads to possible disadvantages in that the unused engines will not be maintained at operating temperature, as is the case when all units are in a common circulating system. If the idle machine temperature drops below the dew point of the products of combustion, corrosive condensate will be formed in the exhaust gas passages each time the idle machine is started. When the volume of water and weight of machinery that must be heated up to operating temperature is large, the volume of condensate is quite significant and some method of draining the condensate is necessary. Some contaminants will get into the lube oil and reduce the service life.

If the machinery gets very cold, it may be difficult to start. Where units are started and stopped with some frequency, it is desirable to provide some off-cycle heating sequence to lessen the exposure to corrosion.

Water level control of separate engine cooling systems that produce steam must take into account the possibility of back flow through the steam nozzle of units that are out of operation. Each machine system may be equipped with a back pressure regulating valve or some form of steam check valve or equalizing line to avoid this difficulty.

Analysis of the current problems of installation costs, available product designs and operating experience indicated that forced circulation hot water heat recovery systems are best suited to installations of about 1000 kw total capacity or smaller and where future expansion is limited by other design considerations. In those projects of much larger capacity, the fluid pumping systems become unwieldy, and making provisions for considerable future increase in capacity is quite difficult. These larger projects are likely to be better served with free convection, ebullient cooled packages for each engine, with a low pressure steam headed connecting the various sources of heat input to the utilization loads. Special water conditioning and testing apparatus can be provided on larger projects and the added complexity of coolant quality control in the steam systems may be readily justified by the greater realiability of the independent engine coolant systems.

APPENDIX B

ANALYSIS BACKGROUND

ANALYSIS

WASTE HEAT PRODUCED BY PLANT

The monthly kWh electrical production for the plant was obtained from NCPC and used as a basis to calculate the heat produced in accordance with the technical data provided in Appendix A, and Graphs 1, 2, 3 and 4. The heat produced was defined as the gross amounts rejected by the engine through the exhaust and jacket water.

RECOVERABLE HEAT

The recoverable heat is defined as the practical amount that can be extracted from the jacket water and exhaust gas per the discussion in Appendix A, less the amount of heat already being recovered and used for other purposes.

MONTHLY HEAT MARKET

Where available, actual user operating data is included in the analysis. In cases where the specific characteristics required estimation, building users are divided into two groups for market evaluation:

1. Non-industrial; including residential, public and light commercial, and
2. Industrial; including garages, warehouses, metal buildings, factories and other similar structures.

The program uses a degree-day model for building heating loads where the load is not known by other means.

In cases where the heat load is known, this value is used as defined as "specified other users".

WATER DISTRIBUTION SYSTEM

Based on the market potential and heat available, the distribution system is selected and sized in accordance with good engineering practice. Consideration is given to the type of recovery to be employed, quality of heat, distance to market, insulated used, as well as thermal and friction losses for the distribution network.

The heat losses for the main and branch lines were calculated based on the length of mains and the number of branches. All systems are assumed to be solid water, for reasons described in Appendix A.

POTENTIAL MARKET UTILIZATION SUMMARY

The potential market utilization summary recaps the heat produced by the generator, the heat available for recovery (recoverable) and the amount which can be utilized by the potential market using jacket water only, exhaust gas only, or exhaust gas plus jacket water if the market is sufficiently large.

Graph 5 shows the relationship between heat produced, heat recoverable, potential market use for the residual jacket water and exhaust heat not used in-plant.

SYSTEM AND MARKET UTILIZATION FACTORS

The following definitions are used for system utilization factors:

JW only: $\frac{\text{Total Heat Currently Used \& Potentially Used (JW)}}{\text{Total Heat Produced}}$

EX only: $\frac{\text{Total Heat Currently Used \& Potentially Used (EX)}}{\text{Total Heat Produced}}$

JW & EX: $\frac{\text{Total Heat Currently Used \& Potentially Used (JW \& EX)}}{\text{Total Heat Produced}}$

JW only: $\frac{\text{Potential Market for Recoverable JW Heat}}{\text{Total Recoverable Heat}}$

EX only: $\frac{\text{Potential Market for Recoverable EX Heat}}{\text{Total Recoverable Heat}}$

JW & EX: $\frac{\text{Potential Market for Combined EX \& JW Recoverable Heat}}{\text{Total Recoverable Heat}}$

FINANCIAL CONSIDERATIONS

In the financial analysis of the systems, the following criteria were employed:

1.	Discount rate	9% per annum
2.	Energy inflation rate	10% per annum
3.	Capital invested	present value

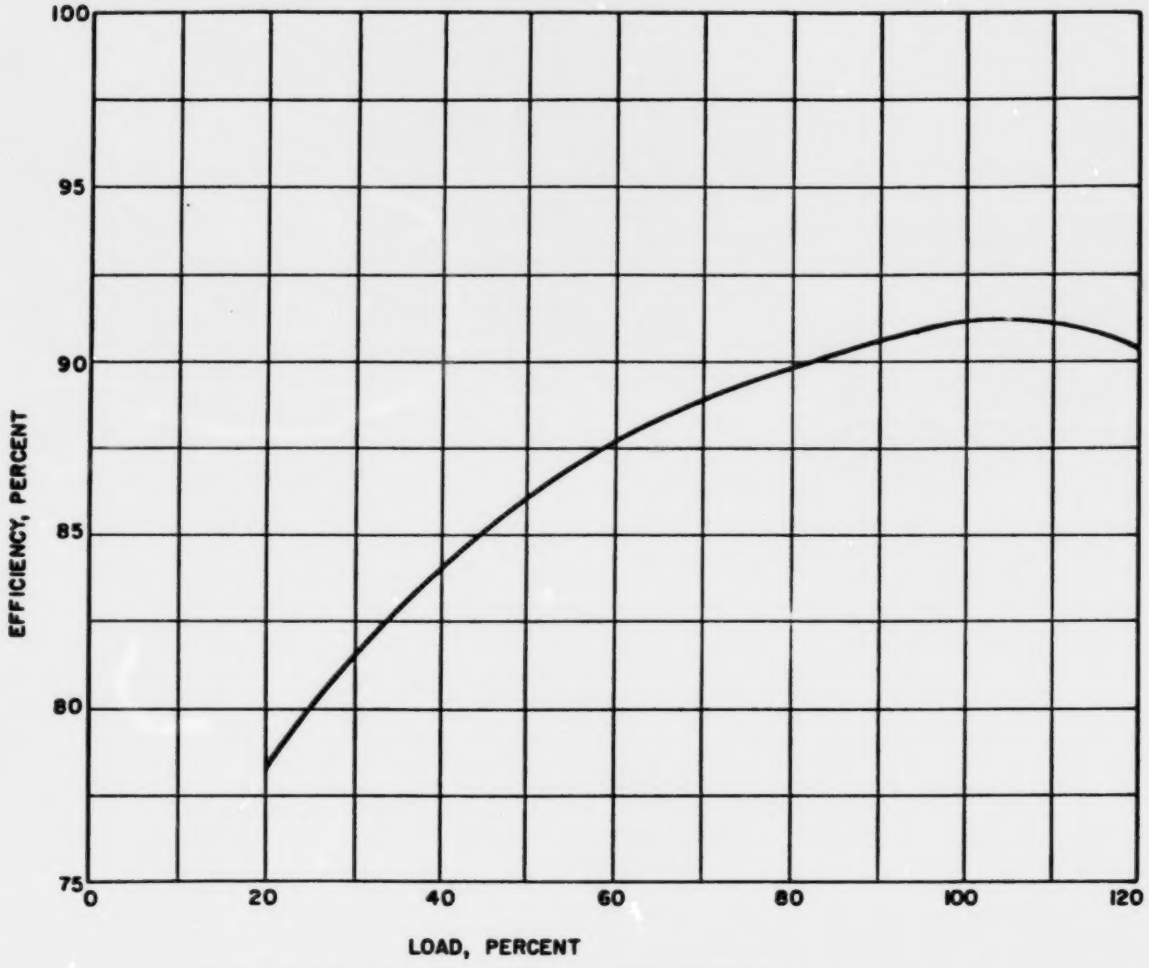
Heating costs per KWh were computed based on fuel costs for the area, and adjusted according to the fuel cost sharing ratio to give a maximum payout of 10 years.

Capital costs of the system conversions include in-plant modifications, distribution system costs and costs necessary for the user to absorb the waste heat.

APPENDIX C

GRAPHS

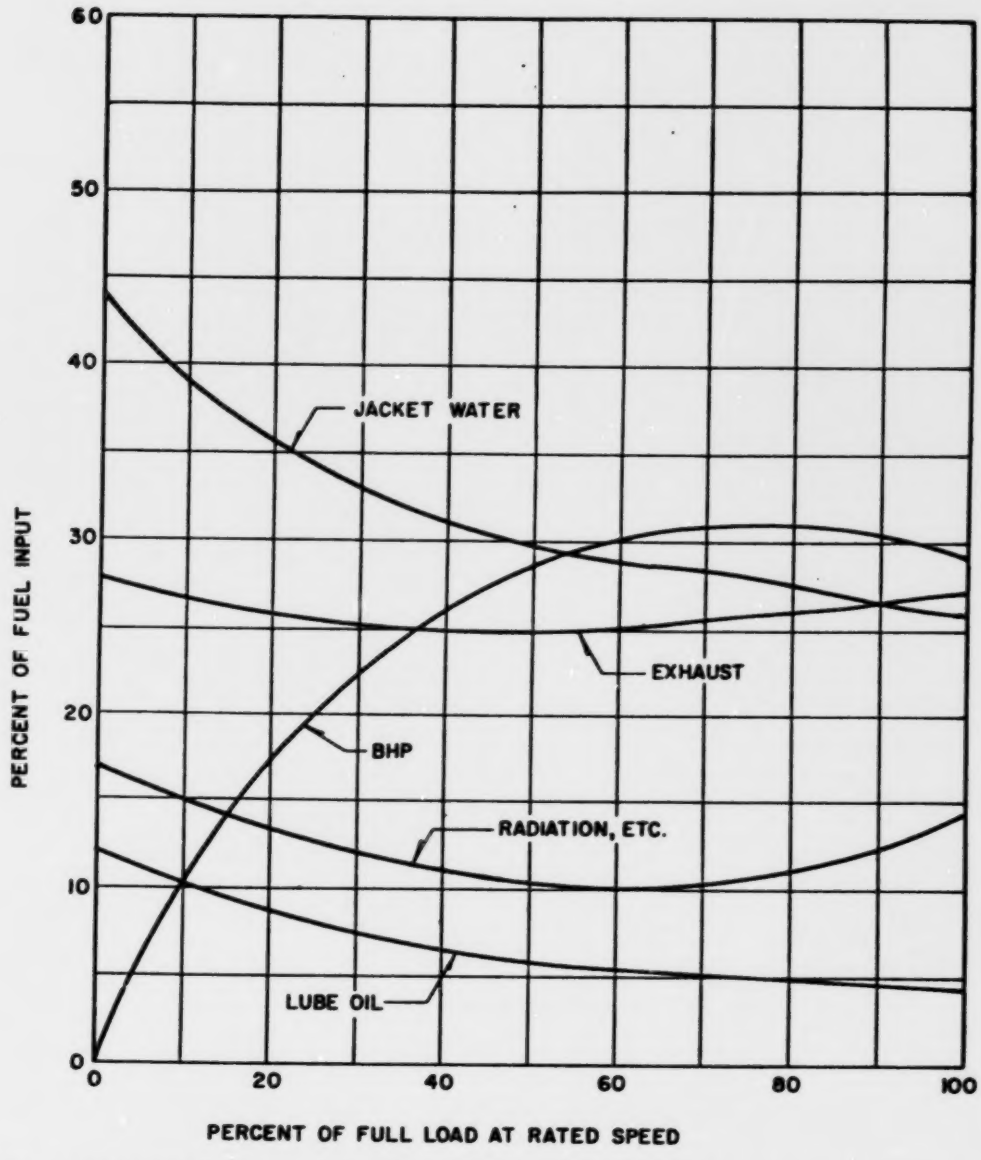
GRAPHS



TYPICAL GENERATOR EFFICIENCY

BASED ON ASHRAE SYSTEMS 1976 BY PERMISSION

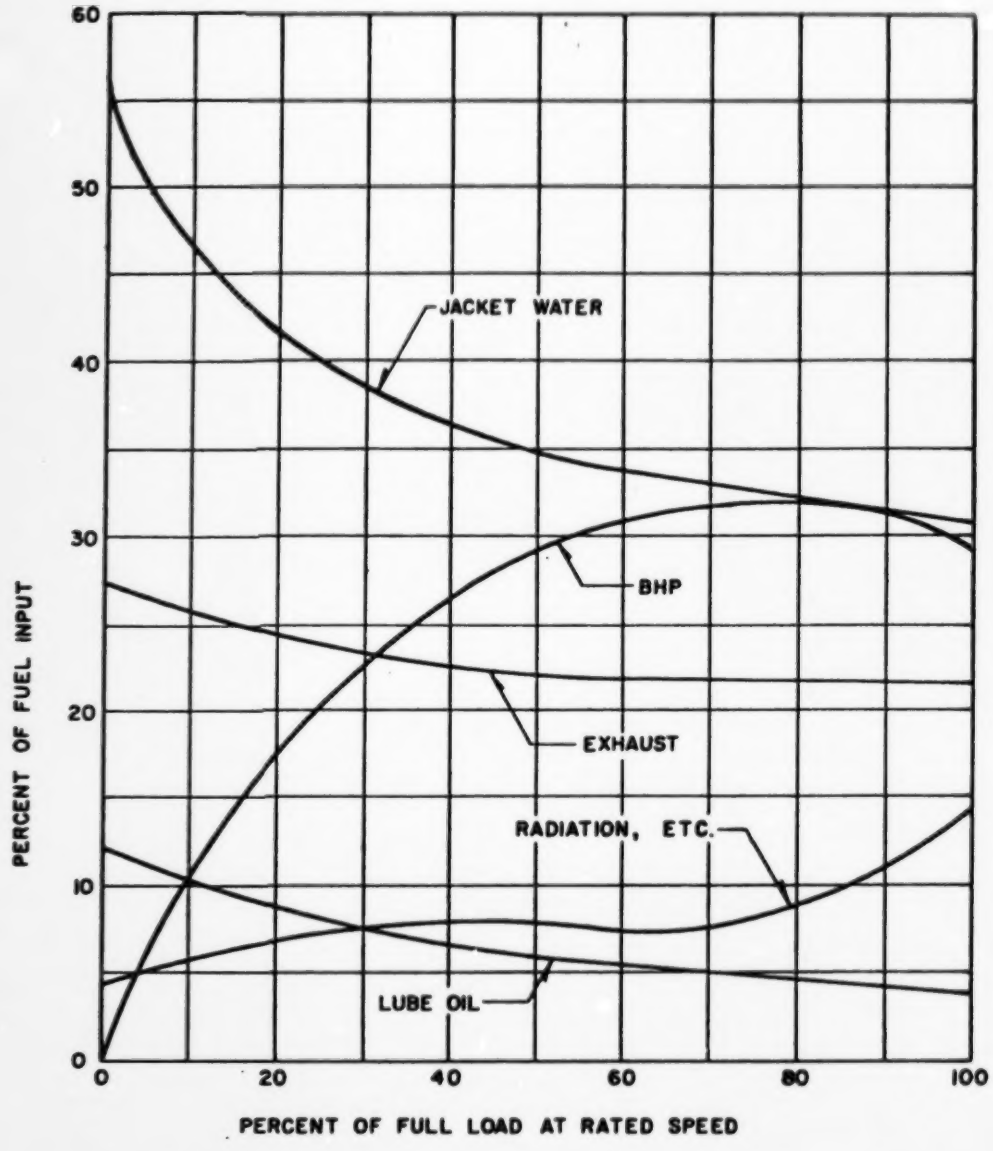
GRAPH 1



HEAT BALANCE FOR TYPICAL UNSUPERCHARGED ENGINE WITH HOT EXHAUST MANIFOLD

BASED ON ASHRAE SYSTEMS 1976 BY PERMISSION

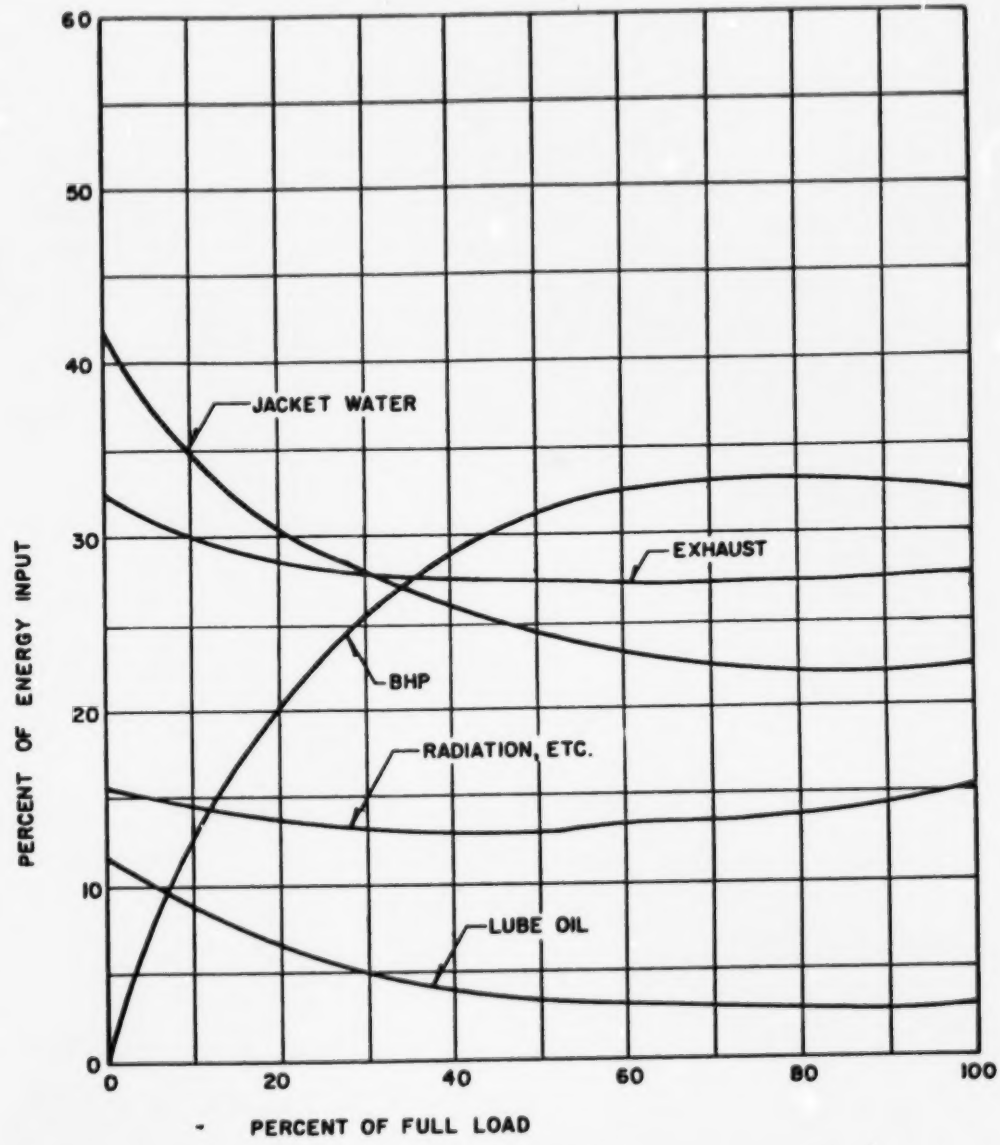
GRAPH 2



HEAT BALANCE FOR TYPICAL UNSUPERCHARGED ENGINE WITH WATER-COOLED EXHAUST MANIFOLD

BASED ON ASHRAE SYSTEM 1976 BY PERMISSION

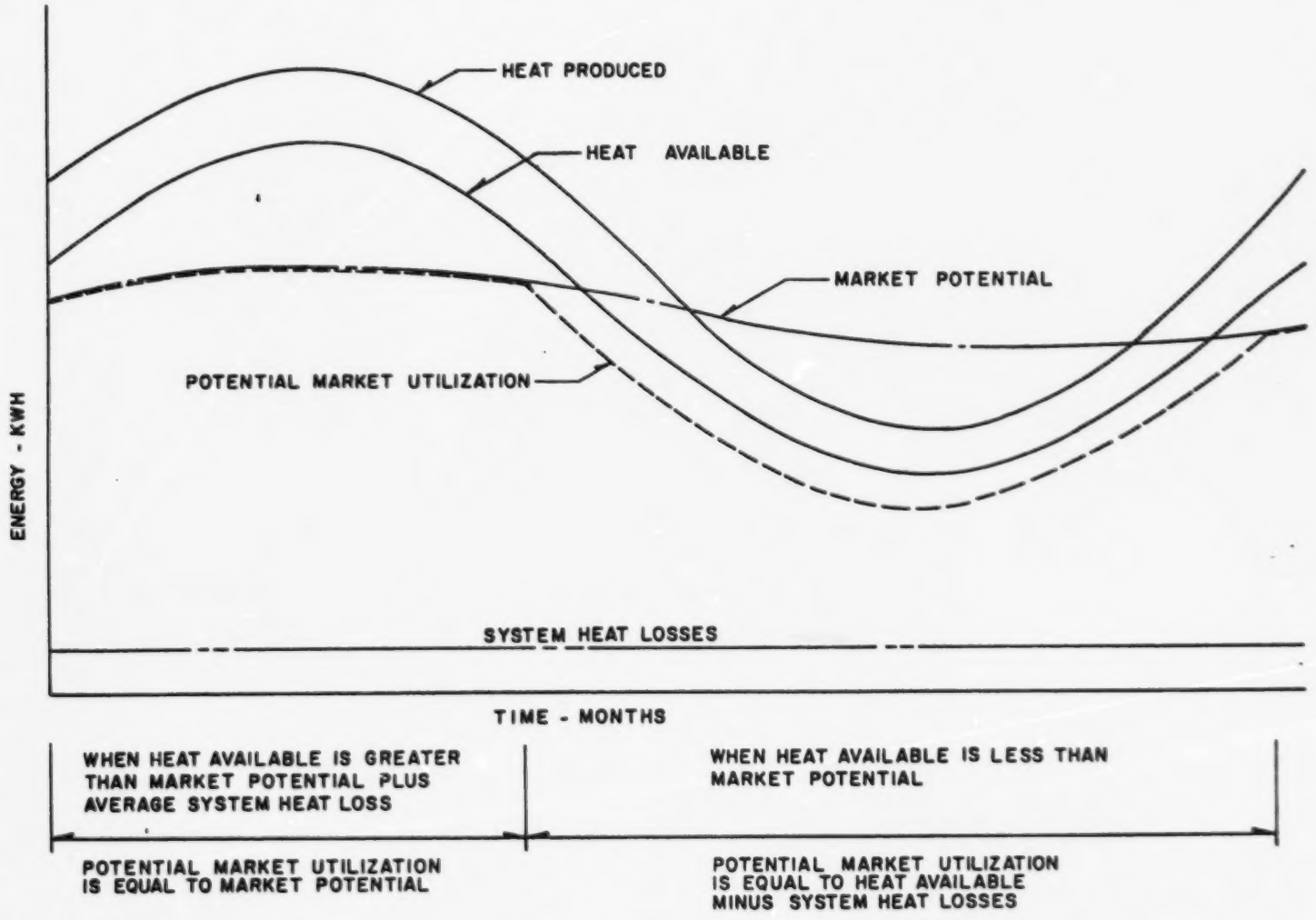
GRAPH 3



HEAT BALANCE FOR TYPICAL TURBOCHARGED ENGINE

BASED ON ASHRAE 1976 SYSTEMS BY PERMISSION

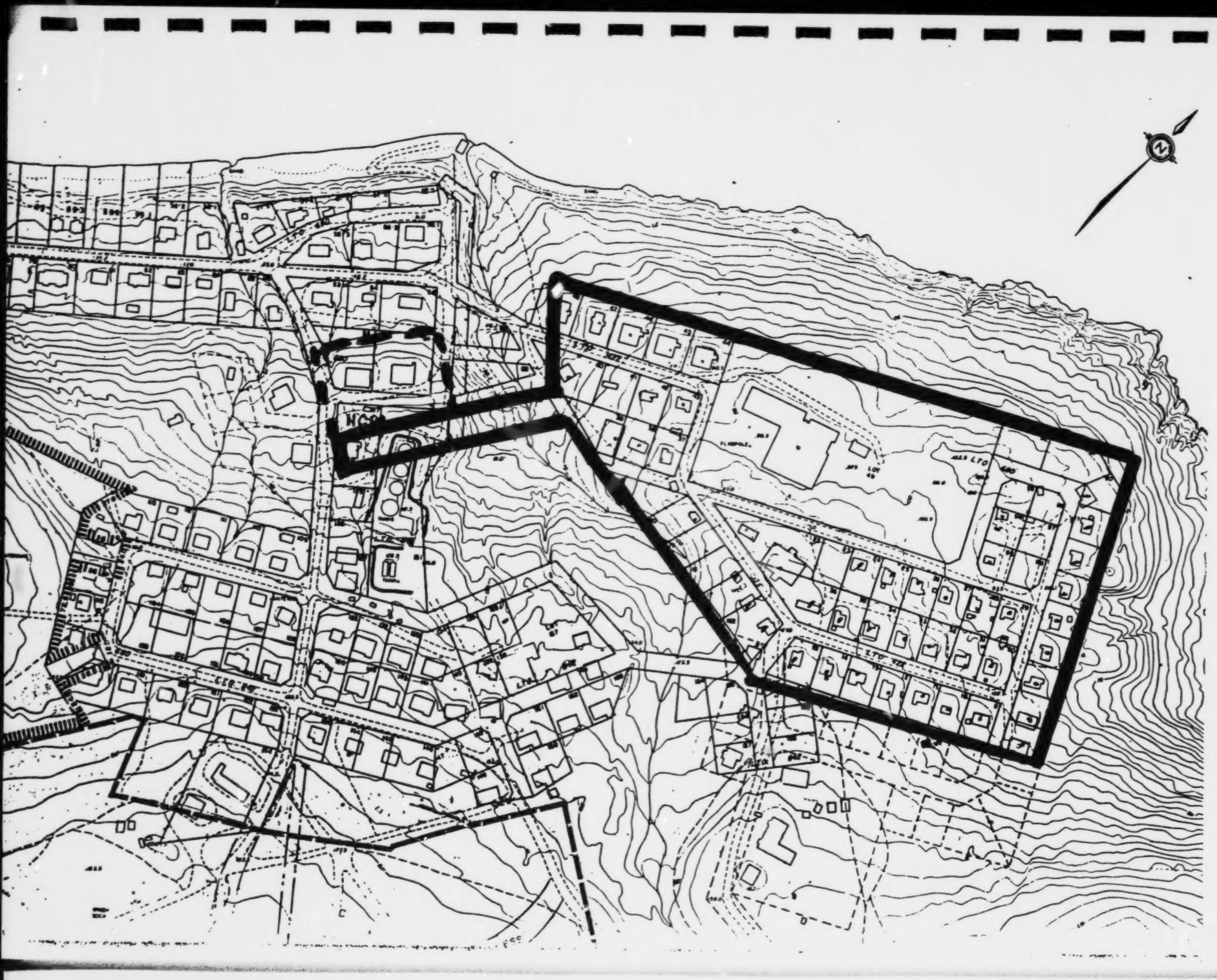
GRAPH 4


HEAT PRODUCED
HEAT AVAILABLE
MARKET POTENTIAL
POTENTIAL MARKET UTILIZATION
ENERGY - KWH
SYSTEM HEAT LOSSES
TIME - MONTHS
WHEN HEAT AVAILABLE IS GREATER THAN MARKET POTENTIAL PLUS AVERAGE SYSTEM HEAT LOSS
WHEN HEAT AVAILABLE IS LESS THAN MARKET POTENTIAL
POTENTIAL MARKET UTILIZATION IS EQUAL TO MARKET POTENTIAL
POTENTIAL MARKET UTILIZATION IS EQUAL TO HEAT AVAILABLE MINUS SYSTEM HEAT LOSSES

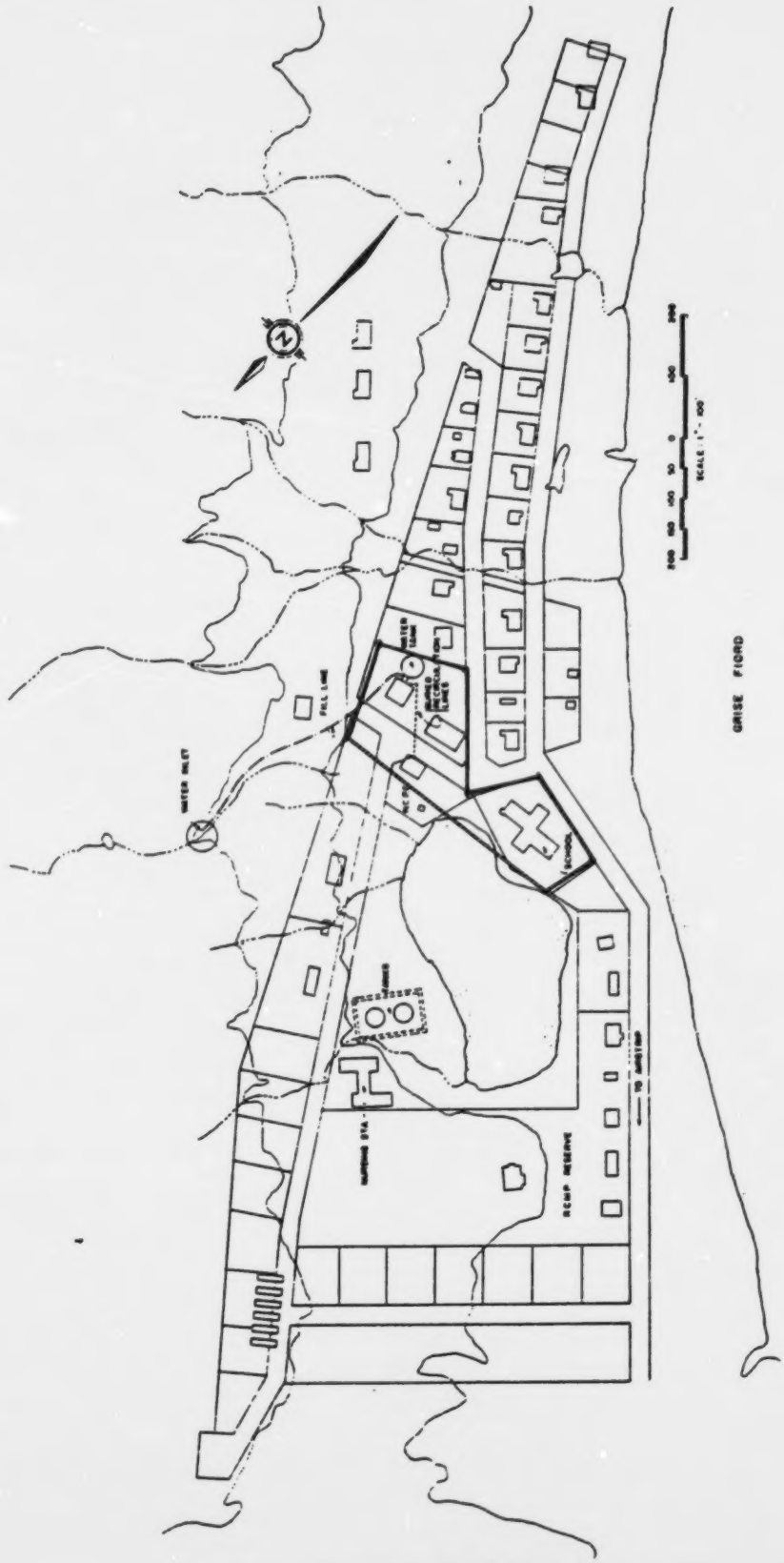
GRAPH 5

HEAT AND MARKET RELATIONSHIPS

MAP - POND INLET



MAP - GRISE FIORD



GRISE FIORD

SCALE -

N.A.P.L.

NO.

POOR
QUALITY
ORIGINAL